MASTER OF SCIENCE
IN
ASTRONAUTICAL ENGINEERING

DARK CURRENT ANALYSIS AND COMPUTER SIMULATION OF TRIPLE-JUNCTION SOLAR CELLS

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This thesis reports the steps taken to characterize the semiconductor properties of triple-junction solar cells. Chemically etching the solar cells exposes each of the three energy producing junctions, InGaP, GaAs and Ge, to probes. Dark current measurements reveal the diode ideality factors of each junction, and these results are compared to current theories on diodes and solar cells. Calculations performed on experimentally obtained values from previous studies and measured values from this research for individual junctions show an expected diode ideality factor for the entire solar cell of 6.2 to 6.4, which is close to the actual production cell value of 5.9. Silvaco International's semiconductor simulation software was used to model the solar cell under dark and illuminated conditions. The simulated dark current yields an ideality factor of 3.45—lower than expected. A spectral analysis equating wavelength of light to current production for each junction within the solar cell is presented, and methods to better match the current produced from each junction are investigated. A current-versus-voltage-curve comparison equates simulated results to actual manufactured cell performance under illumination conditions; simulated values were within 10% for V_{OC} and 15% for I_{SS} in the better performing junctions.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Solar Cell, Multijunction, Tunneling, Software Simulation, Dark Current, GaAs, InGaP, GaInP, Ge

SPACECRAFT INTEGRATED DESIGN TOOLS

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The thesis surveys current software tools to design satellites and develops an integrated spreadsheet-based tool for preliminary spacecraft design. First, several existing and future design tools - both commercially available and company proprietary - are discussed and evaluated. Second, a spreadsheet-based design tool which is generally applicable to any earth-orbiting satellite is developed. Preliminary design of all satellite subsystems is performed on separate sheets of the Excel workbook. Based on user-entered orbital data,

propellant and mass budgets are also calculated. The design technique and spreadsheet implementation is presented along with the underlying "first principles" theory and equations.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Computing and Software

KEYWORDS: Spacecraft, Satellites, Design Tools, Concurrent Engineering

ACTIVE VIBRATION CONTROL METHOD FOR SPACE TRUSS USING PIEZOELECTRIC ACTUATORS AND FINITE ELEMENTS

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This thesis created an analytical model for active vibration control of the NPS space truss using ANSYS. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment at its extremities. With the use of a dSPACE data acquisition and processing system, quartz force transducer and piezoelectric actuator, active controls using an integral plus double integral control law were used to damp out the vibrations caused by a linear proof mass actuator. Vibration reductions on the order of 15-20 dB were obtained with experiment.

The ANSYS finite element model used SOLID5 elements to model the piezoelectric characteristics and ANSYS Parametric Design Language to provide for an iterative approach to an active controls analysis. Comparative data runs were performed with the ANSYS model to determine its similarity to experiment. The analytical model produced power reductions of 18-22 dB, demonstrating the ability to model the control authority with a finite element model. This technique can be used and modified to enhance its flexibility to many types of controls and vibration reduction applications. An analytical model for active control of the NPS space truss using MATLAB/Simulink was also developed as an alternative to the ANSYS model.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Active Vibration Control, Piezoceramic Actuators, ANSYS, Finite Element Method

THE NPS SPACECRAFT COST MODEL: TAILORING CURRENT COMMERCIAL SPACECRAFT COST MODELS FOR NAVAL POSTGRADUATE SCHOOL SATELLITE PROGRAMS

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The successful launch of the Naval Postgraduate School (NPS) Petite Amateur Navy Satellite (PANSAT) led to the development of a follow-on satellite program at NPS. Until now, there did not exist a NPS specific cost modeling procedure to ensure accurate pricing information for program management. From the Preliminary Design Review of NPSat an initial attempt at modeling this program was conducted by the author. This thesis will provide an evaluation of this initial model and address procedures for refining the initial estimate with the purpose of providing a generic NPS Cost Model. This model will tailor current commercial cost model outputs to provide accurate price estimates for NPS specific programs. The commercial cost models used were Science Applications International Corporation's (SAIC) NAFCOM model and Aerospace's Small Satellite Cost Model (SSCM). These models do not take into account a

university atmosphere where staffs and facilities are reduced. A method of tailoring the outputs of these programs was conducted and integrated into an Excel based spreadsheet. The resultant product is the Naval Postgraduate School's first Cost Modeling program which allows NPS satellite program management to input results from the SSCM and NAFCOM models and output expected cost data.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Spacecraft Cost Modeling, Parametric Estimation, Satellite Design

ATTITUDE DETERMINATION OF A THREE-AXIS STABILIZED SPACECRAFT USING STAR SENSORS

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The purpose of this thesis is to investigate the application of a six-state discrete Kalman filter for estimates of angular rates based solely on star sensor data. The satellite is in a Molnyia orbit where orbital angular velocity and orbital angular acceleration are predetermined and stored in the on-board computer; such that they will be available each time a star observation is made. A two-axis star sensor will provide two angles to the estimator whereupon the third "unsensed" angle will be predicted; the rates about all three axes are then estimated. The results show that the rate estimates are accurate to within 10^{-7} r/s, which is equivalent to the data produced by gyroscopes.

DoD KEY TECHNOLOGY AREA: Space Vehicles

KEYWORDS: Kalman, Molnyia, MATLAB, Spacecraft, Satellite, Star Sensor, Star Tracker, Estimation, Rate, Gyroscope